Control of fresh fruit decays by fungicides and generally recognized as safe (GRAS) salts used separately and in combinations

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Abstract: Four fungicides (propiconazole, pyrimethanil, carbendazim and trifloxystrobin) and two generally recognized as safe (GRAS) salts (i.e. sodium bicarbonate and potassium sorbate) were evaluated separately and in mixtures against green and blue mold diseases of navel orange fruits caused by *Penicillium digitatum* and *Penicillium italicum*, respectively. The *in vitro* tests showed that the two fungi were highly sensitive to propiconazole, pyrimethanil and trifloxystrobin, and moderately sensitive to carbendazim. GRAS salts were the least effective against these fungi, however, potassium sorbate was inferior to sodium bicarbonate. Interestingly, the addition of salt to the fungicide-amended medium enhanced its fungicidal activity against *P. digitatum* and *P. italicum*. The results obtained from *in vivo* tests proved the postulation that addition of salts to the fungicides greatly increased their efficiencies against the incidence of green and blue mold diseases.

Keywords: Orange, Green mold, Blue mold, *Penicillium digitatum*, *P.italicum*, Fungicides, Sodium bicarbonate and Potassium sorbate

1. Introduction

Navel orange (*Citrus sinensis* L. Osbeck) is one of the most important and widely distributed fruit crops in the world. It has essential factors responsible for its nutritional and health benefits such as organic acids, vitamins, volatiles, amino acids, sugars, phenolics and carotenoids (**Cerdan-Calero *et al.*, 2012**). This crop during postharvest handling and storage, is subjected to be attacked by certain diseases including green and blue molds caused by *Penicillium digitatum* (Pers.: Fr.) Sacc. and *Penicillium italicum* Wehmer, respectively. These diseases are the most important diseases of navel orange, and thus caused considerable economic losses (**Palou, 2014**). In storage, the disease can lead to total breakdown and fluidity of infected fruits. The juices that are dripping from the infected fruits help to spread the pathogens to healthy fruits (**Eckert and Eaks, 1989**). Good practices such as avoidance of injury during harvesting and transportation as well as sanitation of packinghouses and warehouses will reduce the incidence of postharvest diseases.

Usage of synthetic postharvest fungicides is the most effective method to reduce the incidence of decays. Several fungicides including propiconazole (**McKay *et al.*, 2012 a & b** and **Erasmus *et al.*, 2015**), pyrimethanil (**Kanetis *et al.*, 2008 a & b; Erasmus *et al.*, 2015 and Youssef *et al.*, 2017**), carbendazim (**Marei and Abd-Elgaliel, 2018**) and trifloxystrobin (**El-Khawaga-Maii, 2006 and Khalifa and Sameer, 2014**) were evaluated for controlling postharvest diseases by several means of applications. However, the intensive and continuous use of these chemicals is increasingly leading to major problems, such as human health issues, environmental pollution and the proliferation of resistant fungal biotypes (**Palou *et al.*, 2008 and Palou, 2018**). Therefore, alternative methods for postharvest diseases control are needed.

Treatment of fruit with sodium bicarbonate was shown to reduce the incidence of green and blue molds of citrus fruit caused by *P. digitatum* and *P. italicum*, respectively, which are in accordance with those obtained previously (**Zamani *et al.*, 2008; Askarne *et al.*, 2011; McKay *et al.*, 2012a; Helalia and Sameer, 2014; Fallanaj *et al.*, 2016 and Palou, 2018**). Also, potassium sorbate was superior for the control of postharvest *Penicillium* decay of citrus fruit (**Smilanick *et al.*, 2008; Montesinos-Herrero *et al.*, 2009; Palou *et al.*, 2009; Parra *et al.*, 2014; Youssef *et al.*, 2017 and Palou, 2018**). Compared to sodium bicarbonate, potassium sorbate has the advantage of fewer disposal issues caused by the absence of sodium and lower pH and salinity, but it has the disadvantages of higher price and phytotoxicity risk. Probably for these reasons, the use of potassium sorbate solutions in citrus packinghouses is less than that of sodium bicarbonate solutions (**Smilanick *et al.*, 2008; Montesinos-Herrero *et al.*, 2009 and Palou, 2018**). Also, the addition of sodium bicarbonate or potassium sorbate improved the performance of citrus postharvest fungicides for controlling green and blue mold decays. Sodium bicarbonate enhanced the effect of many fungicides such as imazalil, propiconazole, pyrimethanil, fludioxonil, thiabendazole and azoxystrobin (**Smilanick *et al.*, 2008; Adaskaveg, 2008; McKay *et al.*, 2012a; Aquino *et al.*, 2013a and Helalia and Sameer, 2014**) for controlling citrus postharvest diseases. Also, potassium sorbate potentiated the activity of imazalil, pyrimethanil, and thiabendazole against *P. digitatum* (**Smilanick *et al.*, 2008**; **Montesinos-Herrero *et al.*, 2009 and Aquino *et al.*, 2013b**).

The aim of this study was to evaluate four fungicides (propiconazole, pyrimethanil, carbendazim and trifloxystrobin) and two generally recognized as safe (GRAS) substances (sodium bicarbonate and potassium sorbate) used alone or in combinations (fungicide + salt) for controlling green and blue mold on orange fruits.

2. Materials and Methods

The present work was conducted at the laboratory of Plant Protection Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt during 2018.

2.1.Fungi:

An identified isolates of *Penicillium digitatum* and *P. italicum*, the causal agents of green and blue molds of citrus fruits, respectively, were obtained from Plant Disease Institute, Agricultural Research Center, Giza.

2.2.Compounds:

Four fungicides, i.e. propiconazole, (IUPAC) (±) - 1-[2-(2,4-dichlorophenyl)-4-propyl-1,3- dioxolan -2- yl - methyl] -1*H* -1,2,4 triazole (Teliozed, 25 % E.C.), pyrimethanil, (IUPAC) N-(4,6-dimethylpyrimidin-2-yl)aniline (Pyrimdol 40 % S.C.), carbendazim, (IUPAC) methyl benzimidazol-2-yl-carbamate (Kemazed 50 % W.P.) and trifloxystrobin, (IUPAC) methyl (E)-methoxyimino-{(E)-α-[1-(α,α,α-trifluoro-m-tolyl)ethylideneaminooxy]-o-tolyl}acetate (Flint 50 % W.G.) and two generally recognized as safe (GRAS) substances, i.e. sodium bicarbonate ($NaHCO_3$) and potassium sorbate ($C_6H_7KO_2$) were used.

2.3.*In vitro* fungitoxicity test:

A study was conducted to evaluate the fungicidal activity of the tested fungicides and salts. Each fungicide was diluted in sterile distilled water, and then added to cooled PDA medium at concentrations of 0.01, 0.05, 0.1, 0.5, 1.0, 5.0, 10.0, 25.0, 50.0, 75.0 and 100.0 µg a.i. / ml. Salts were amended in PDA medium at concentrations of 100, 250, 500, 750, 1000, 1500, 2000, 2500 and 3000 µg / ml. In other trials, PDA media amended with different concentrations of each fungicide were further amended with 1000 and 2000 µg / ml of sodium bicarbonate or potassium sorbate. The poisoned media were poured in plates (9 cm diameter), other plates containing compounds-free medium were used as control treatment. The medium was seeded by 0.4 cm diameter disk, removed from 7 day-old culture of the fungus, on solidified medium and incubated for 7 days at 25º C. Each treatment was replicated four times. Growth on the fungicides, salts and their mixtures amended media was determined by measuring the colony diameter (cm). The percentage of growth inhibition was calculated relative to the control. The concentration giving 50 % liner growth inhibition (EC_{50}) was determined by regression analysis of the log probit transformed data (**Finney, 1971**).

2.4.Control of green and blue molds (*In vivo* tests):

The trial was conducted to investigate the efficiency of fungicides and salts applied alone or in mixtures (fungicide + salt) for controlling the incidence of artificial infection with green and blue molds on navel orange under laboratory conditions. Healthy uniform navel oranges were used. The fruits were washed with soap, rinsed with fresh water, and washed again with 70 % ethanol for surface sterilization. After drying, the fruits were inoculated artificially with *P. digitatum* or *P. italicum*. Inoculation was performed according to **Eckert & Kolbezen (1977)** by making a scratch 1.0 cm long and 0.1 mm deep in the rind on both sides of each fruit and then applying dry spores to the scratches with a small brush. Twenty four hours after inoculation, orange fruits were treated with the tested fungicides, salts and their mixtures by dipping method in the solutions for 30 sec. Fungicides were evaluated either separately or in mixtures with sodium bicarbonate or potassium sorbate at 1000, 1500 and 2000 µg a.i. / ml, whereas sodium bicarbonate or potassium sorbate was evaluated separately at $1x10^4$, $2x10^4$ and $3x10^4$ µg a.i. / ml, as recommended concentrations, and in mixtures with the tested fungicides at 1000 and 2000 µg a.i. / ml. All treatments were replicated 3 times and each replicate contained 8 oranges. Other fruits were dipped in water and used as control. The treated fruits were air – dried, and inspected for decay 15 days after storage in plastic bags at 25º C. The efficacy of each treatment was determined according to the equation described by **Samoucha & Cohen (1989)** as follows: PCE = 100 (1- x / y), where PCE percentage of control efficacy, x = number of decayed fruits in treatment and y = number of decayed fruits in control treatment. The results were statistically analyzed according to **Snedecor & Cochran (1969)**.

3. Results and Discussion

3.1.Sensitivity of *Penicillium digitatum* and *P. italicum* to the fungicides and salts used separately.

The effects of the tested fungicides and salts on growth of *P. digitatum* and *P. italicum* were determined by measuring the growth of the fungus on PDA media containing different concentrations of each compound and the concentration that inhibits 50 % of the fungal growth (EC_{50}) was calculated. Results in Tables (1 and 2) showed that increasing the concentration of the examined compound gradually reduced the growth of the tested fungus. At the concentration of 75.0 µg / ml, both propiconazole and pyrimethanil completely inhibited the fungal growth of both fungi, whereas carbendazim and trifloxystrobin exhibited only less than 90 % inhibition. At this concentration, sodium bicarbonate and potassium sorbate did not affect the growth of both fungi and the effect of these salts started at concentration of 100 µg / ml. Depending on the EC_{50} values of Tables (1 and 2), the inhibitory effect of the tested compounds could be arranged descendingly as: propiconazole > pyrimethanil > trifloxystrobin > carbendazim > sodium bicarbonate > potassium sorbate and that true for each fungus. However, *P. italicum* showed higher sensitivity to the examined compounds than *P. digitatum*

Data listed in Tables (1 and 2) showed high efficacy of propiconazole against *P. digitatum* and *P. italicum* under laboratory conditions. This result is in accordance with those of **McKay *et al.* (2012b)**

Table 1. Growth inhibition percent of *Penicillium digitatum* grown on PDA medium amended with different concentrations (µg a.i* / ml) of fungicides and salts.

Conc.µg/ml	Fungicides				Conc. µg/ml	Salts	
	Propiconazole	Pyrimethanil	Carbendazim	Trifloxystrobin		Sodium bicarbonate	Potassium sorbate
0.01	44.44	18.56	3.67	9.22	100	5.56	1.89
0.05	53.77	29.67	5.56	18.56	250	9.22	3.67
0.1	63.00	37.00	11.11	24.11	500	16.67	11.11
0.5	72.22	44.44	16.67	35.22	750	24.11	20.33
1.0	77.77	55.56	22.22	40.78	1000	40.78	29.67
5.0	81.55	72.22	33.33	51.88	1500	55.56	44.44
10.0	88.88	83.33	40.77	63.00	2000	75.89	68.56
25.0	94.44	88.89	51.85	75.89	2500	85.22	79.67
50.0	100.0	90.78	59.22	81.44	3000	90.78	85.22
75.0	100.0	100.0	77.78	88.88	-	-	-
100.0	100.0	100.0	88.89	94.44	-	-	-
EC_{50}**	0.043	0.44	11.48	1.70	EC_{50}**	1071.5	1412.5

* Active ingredient

** EC_{50} = A concentration as µg a.i / ml that give 50 % inhibition of the fungal growth

Table 2. Growth inhibition percent of *Penicillium italicum* grown on PDA medium amended with different concentrations (µg a.i* / ml) of fungicides and salts.

Conc.µg/ml	Fungicides				Conc. µg/ ml	Salts	
	Propiconazole	Pyrimethanil	Carbendazim	Trifloxystrobin		Sodium bicarbonate	Potassium sorbate
0.01	46.33	22.22	3.67	18.56	100	5.56	3.67
0.05	55.55	38.89	5.56	27.78	250	11.11	7.44
0.1	64.48	61.11	13.00	42.55	500	14.78	13.00
0.5	74.07	66.66	18.52	48.11	750	27.78	18.56
1.0	81.48	74.11	25.89	55.56	1000	46.33	35.22
5.0	83.33	87.04	33.33	66.66	1500	59.22	50.00
10.0	90.74	88.89	50.00	72.22	2000	74.11	70.33
25.0	96.33	90.74	57.44	77.78	2500	90.78	77.78
50.0	100.0	100.0	70.37	81.44	3000	94.44	88.89
75.0	100.0	100.0	81.44	88.89	-	-	-
100.0	100.0	100.0	92.56	92.56	-	-	-
EC_{50}**	0.03	0.11	6.92	0.56	EC_{50} **	955.00	1288.2

* Active ingredient

* EC_{50} = A concentration as µg a.i / ml that give 50 % inhibition of the fungal growth

who found that the EC_{50} value of propiconazole was 0.008 µg / ml against mycelial growth of *P. digitatum*. Also, pyrimethanil was highly effective against *P. digitatum* and *P. italicum* growth. These results were confirmed by **Kanetis *et al*. (2008a)** who found that the EC_{50} values of pyrimethanil were 0.208-0.413 and 0.01-0.082 µg / ml against mycelial growth of *P. digitatum* and *P. italicum*, respectively. Moreover, **Khalifa and Sameer (2014)** showed that *P. digitatum* was sensitive to trifloxystrobin with mean EC_{50} value of 0.263 µg / ml. Carbendazim fungicide exhibited a moderate effect against the growth of *P. digitatum* and *P. italicum*. This result was confirmed by **Marei and Abd-Elgaliel (2018)** who found that the EC_{50} value of carbendazim to *P. digitatum* was 13.63 mg / L. Based on the EC_{50} values, the isolates of *P. digitatum* and *P. italicum* are considered to be more sensitive to propiconazole, pyrimethanil and trifloxystrobin than carbendazim. **Helalia and Sameer (2014)** found that ergosterol biosynthesis inhibitors such as propiconazole and quinol – oxidizing inhibitors (QoI) such as trifloxystrobin are more potent to *P. digitatum* growth than methyl benzimidazole carbamate such as carbendazim. It has been suggested that ergosterol biosynthesis inhibitors could be used for controlling fungi – resistant to benzimidazole fungicides (**Eckert and Wild, 1983**).

The results also indicated that salts at high concentrations (2000, 2500 and 3000 µg / ml) possess an inhibitory effect to mycelial growth of *P. digitatum* and *P. italicum*. These results were confirmed by **Zamani *et al*. (2009)** who found that sodium bicarbonate at different concentrations decreased spore germination of *P. digitatum* from 11 % to 83 %. **Helalia and Sameer (2014)** found that the EC_{50} value of sodium bicarbonate was 1367 µg / ml against mycelial growth of *P. digitatum*. Potassium sorbate at 2 % completely inhibited the fungal growth of *P. digitatum* and *P. italicum* (**El-Mougy *et al*., 2008**). An inverse relation between *P. expansum* growth and potassium sorbate concentration was observed by **Fadda**

***et al.* (2015)**. Based on the EC_{50} values of salts, sodium bicarbonate was more potent to the tested fungi than potassium sorbate. This result was confirmed by **Smilanick *et al.* (2008)** and **Palou (2018)**.

3.2. Sensitivity of *P. digitatum* and *P. italicum* to mixtures of fungicides and salts.

Results represented in Tables (3 and 4) show the efficiency of the tested fungicides used separately or mixed with the salts against *P. digitatum* and *P. italicum*. Concerning fungicide – salt mixtures, the results clearly indicated that the EC_{50} values of these mixtures were lower than the values of the fungicide alone. Accordingly the addition of salt (sodium bicarbonate or potassium sorbate) enhanced the potency of the fungicides against the growth of *P. digitatum* and *P. italicum*. This potentiation effect differed according to the used concentration of the salt and the type of the fungicide. Regardless the concentration of salt added, the potentiating effect of sodium bicarbonate was more apparent than with potassium sorbate. However, this potentiation increased with increasing the concentration of added salt. For example, carbendazim is considered less effective than other fungicides where it had EC_{50} values equal to 11.48 and 6.92 µg / ml for *P. digitatum* and *P. italicum*, respectively. However, these values decreased to 2.23 and 1.57 µg / ml, respectively, when 2000 µg / ml of sodium bicarbonate was added, indicating that its fungitoxic activity increased by 5.15- and 4.41- fold, respectively. Indeed, potassium sorbate was lower effective than sodium bicarbonate, whereas fungitoxic activity of carbendazim was increased by 3.61- and 3.87- fold, respectively, when 2000 µg / ml of potassium sorbate was added.

Generally, the fungicidal activity of the tested fungicides, particularly carbendazim, was increased by adding sodium bicarbonate or potassium sorbate to the fungicides. These data are in agreement with previous studies (**Adaskaveg, 2008; Smilanick *et al.*, 2008; Montesinos-Herrero *et al.*, 2009 & 2011; McKay *et al.*, 2012a; Aquino *et al.*, 2013 a & b; Helalia and Sameer, 2014 and Palou, 2018**).

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Table 3. Effect of mixtures of salts with different fungicides against *Penicillium digitatum*.

Fungicides	EC_{50}* of the fungicides separately µg/ml	EC_{50}* (µg/ml) of the fungicides + Sodium bicarbonate at				EC_{50}*(µg/ml) of the fungicides + Potassium sorbate at			
		1000 µg/ml		2000 µg/ml		1000 µg/ml		2000 µg/ml	
		EC_{50}*	P.E.**	EC_{50}*	P.E.**	EC_{50}*	P.E.**	EC_{50}*	P.E.**
Propiconazole	0.043	0.031	1.39	0.026	1.65	0.040	1.08	0.029	1.48
Pyrimethanil	0.440	0.190	2.32	0.120	3.67	0.280	1.57	0.200	2.20
Carbendazim	11.480	3.790	3.03	2.230	5.15	3.810	3.01	3.180	3.61
Trifloxystrobin	1.700	0.660	2.58	0.430	3.95	0.680	2.50	0.540	3.15

* EC_{50} = A concentration as µg a.i / ml that give 50 % inhibition of the fungal growth
** P.E. = Potentiating Effect = EC_{50} of the fungicide alone / EC_{50} of the mixture

Table 4. Effect of mixtures of salts with different fungicides against *Penicillium italicum*.

Fungicides	EC_{50}* of the fungicides separately µg/ml	EC_{50}* (µg/ml) of the fungicides + Sodium bicarbonate at				EC_{50}*(µg/ml) of the fungicides + Potassium sorbate at			
		1000 µg/ml		2000 µg/ml		1000 µg/ml		2000 µg/ml	
		EC_{50}*	P.E.**	EC_{50}*	P.E.**	EC_{50}*	P.E.**	EC_{50}*	P.E.**
Propiconazole	0.030	0.018	1.67	0.010	3.00	0.022	1.36	0.017	1.76
Pyrimethanil	0.110	0.082	1.34	0.055	2.00	0.091	1.21	0.064	1.72
Carbendazim	6.920	1.960	3.53	1.570	4.41	2.630	2.63	1.790	3.87
Trifloxystrobin	0.560	0.270	2.07	0.160	3.50	0.310	1.81	0.210	2.67

* EC_{50} = A concentration as µg a.i / ml that give 50 % inhibition of the fungal growth
** P.E. = Potentiating Effect = EC_{50} of the fungicide alone / EC_{50} of the mixture

3.3. Control of green and blue molds (*In vivo* tests)

The effect of fungicides at 1000, 1500 and 2000 µg / ml were evaluated separately and in mixtures with 1000 and 2000 µg / ml of salts for controlling green and blue mold diseases on orange fruits. Moreover, the effects of both salts at $1x10^4$, $2x10^4$ and $3x10^4$ µg / ml, as recommended concentrations, were evaluated separately. Results listed in Tables (5 and 6) showed that all the fungicides and salts separately had curative activity when applied 24 hrs. after infections depending on the used concentration. Results also indicated that all compounds reduced the incidence of green and blue mold on orange fruits. Increasing the concentration of compounds resulted in increment their effectiveness against the pathogen. Propiconazole and pyrimethanil seemed to be the most effective fungicides followed by trifloxystrobin and later carbendazim. The separate treatments of both salts at higher concentration of ($3x10^4$ µg / ml) gave less than 71 % control efficiency of both green and blue mold diseases. Results in Tables (5 and 6) showed that the addition of sodium bicarbonate and potassium sorbate to the fungicidal treatments greatly increased their efficiencies against the incidence of green and blue mold diseases and reduced their concentrations required to give the best control rates. The addition of 2000 µg / ml sodium bicarbonate and potassium sorbate to the tested fungicidal treatments, propiconazole, pyrimethanil, carbendazim and trifloxystrobin, each at 1500 µg / ml raised their fungicidal activities against green mold disease (Table 5) from 70.83, 66.67, 45.83 and 54.17 to 91.67, 83.33, 75.00 and 83.33 % and to 87.50, 83.33, 66.67 and 79.17 %, respectively. Moreover, the fungicidal activities of the tested fungicides at 2000 µg / ml ranged from 70.83 – 87.50 % which raised to 91.67 – 100 % and to 87.50 – 100 % when the same concentration was combined with 2000 µg / ml sodium bicarbonate and potassium sorbate, respectively. Also, the PCE values of these fungicides used alone at 1500 µg / ml against blue mold disease (Table 6) were 70.83, 70.83, 54.17 and 50.00 %, respectively, which reached 95.83, 95.83, 83.33 and 87.50 %, and reached 91.67, 91.67, 75.00 and 79.17 % when both sodium bicarbonate and potassium sorbate, respectively, were added at 2000 µg / ml. Moreover, when propiconazole and pyrimethanil were applied separately at 2000 µg / ml, they exhibited 91.67 and 79.17 PCE, respectively. However, both fungicides at the same concentration completely prevented the incidence of the disease when mixed with 2000 µg / ml of sodium bicarbonate and potassium sorbate Results listed in Tables (5 and 6) showed that all fungicides treatments reduced the incidence of green and blue mold diseases caused by *P. digitatum* and *P. italicum*, respectively, on orange fruits. The results obtained are in agreement with those obtained by many investigators. **Adaskaveg (2008)** indicated that propiconazole was the promising candidate for the control of postharvest decay on citrus fruits caused by *Penicillium* spp. Propiconazole was highly effective against several important decays, including green and blue mold (**McKay *et al*., 2012a and Erasmus *et al*., 2015**). Pyrimethanil effectively controls green and blue mold diseases and could be used to control isolates of *Penicillium* resistant to other fungicides (**Kanetis *et al*., 2008b; Smilanick *et al*., 2008 and Erasmus *et al*., 2015**). Pyrimethanil has been registered in USA against citrus green and blue molds (**Youssef *et al*., 2017**). Carbendazim is used for the control of a wide range of fungal diseases including postharvest decays on citrus fruits (**Marei and Abd-Elgaliel, 2018**). Trifloxystrobin was reported in controlling green mold disease in orange fruits (**Khalifa and Sameer, 2014**).

Results listed in Tables (5 and 6) showed that the salts, sodium bicarbonate and potassium sorbate used alone could be used to control the incidence of green and blue mold diseases on orange fruits. Previous researchers (**Zhang and Swingle, 2003; El-Mougy *et al*., 2008; Smilanick *et al*., 2008; Valencia-Chamorro *et al*., 2008;**

References

Adaskaveg, J. E. (2008): Evaluation of new postharvest treatments to reduce postharvest decays and improve fruit quality in citrus packinghouse operations. Plant Pathology and Microbiology, UC/Riverside.

Aquino, S.D.; Fadda, A.; Barberis, A.; Palma, A.; Angioni, A. and Schirra, M. (2013b): Combined effects of potassium sorbate, hot water and thiabendazole against green mould of citrus fruit and residue levels. Food Chemistry, 141, (2): 858-864.

Aquino, S.D.; Palma, A.; Angioni, A. and Schirra, M. (2013a): Residue levels and efficacy of fludioxonil and thiabendazole in controlling postharvest green mold decay in citrus fruit when applied in combination with sodium bicarbonate. J. Agric. Food Chem., 61 (2): 296-306.

Askarne, L.; Talibi, I.; Boubaker, H.; Serghini, M.A.; Boudyach, E. and Ait, A. (2011): Effects of organic acids and salts on the development of *Penicillium italicum*: The causal agent of citrus blue mold. Plant Pathology Journal, 10 (3): 99-107.

Cerdan-Calero, M.; Sendra, J.M.; Sentandreu, E. (2012): Gas chromatography coupled to mass spectrometry analysis of volatiles, sugars, organic acids and amino acids in Valencia late orange juice and reliability of the automated mass spectral deconvolution and identification system for their automatic identification and quantification. J. Chromatogr. A, 1241: 84-95.

El-Khawaga- Maii, A. (2006): Effect of antioxidants on the efficacy of some fungicides. Ph.D. Thesis, Fac. of Science, Al-Azhar Univ.

El-Mougy, N.S.; El-Gamal, N.G. and Abd-El-Kareem, F. (2008): Use of organic acids and salts to control postharvest diseases of lemon fruits in Egypt. Arch. Phytopathol. Plant Prot., 41: 467-476

Erasmus, A.; Lennox, C.L.; Korsten, L.; Lesar, K. and Fourie, P.H. (2015): Imazalil resistance in *Penicillium digitatum* and *P. italicum* causing citrus postharvest green and blue mould: Impact and options. Postharvest Biology and Technology, 107: 66-76.

Fadda, A.; Barberis, A.; Aquino, S.D.; Palma, A.; Angioni, A.; Lai, F. and Schirra, M. (2015): Residue levels and performance of potassium sorbate and thiobendazole and their co-application against blue mold of apples when applied as water dip treatments at 20 or 53º C. Postharvest Biology and Technology, 106: 33-43.

Fallanaj, F.; Ippolito, A.; Ligorio, A.; Garganese, F.; Zavanella, C.; Sanzani, S.M. (2016): Electrolyzed sodium bicarbonate inhibits *Penicillium digitatum* and induces defence responses against green mould in citrus fruit. Postharvest Biology and Technology, 115: 18-29.

Feliziani, E.; Smilanick, J.L.; Margosan, D.A.; Mansour, M.F.; Romanazzi, G.; Gu, S.; Gohil, H.L. and Rubio-Ames, Z. (2013): Preharvest fungicide, potassium sorbate, or chitosan use on quality and storage decay of table grapes. Plant Dis., 97: 307-314.

Finney, D.I. (1971): Probit analysis. Cambridge University Press, London, 450 p. **Helalia, A.R. and Sameer, W.M. (2014)**: Efficacy of fungicides – sodium bicarbonate combination on citrus postharvest.

Table 5. Percentage of control efficiency (PCE) of different concentrations (μg/ml) of fungicides and salts alone or in mixtures against incidence of green mold on orange fruits caused by *Penicillium digitatum*.

Treatments	Conc. μg/ml	Percentage of control efficiency (PCE)					L.S.D. at 5%
		Separated treatment	Candidate sodium bicarbonate concentrations		Candidate potassium sorbate concentrations		
			1000 μg/ml	2000 μg/ml	1000 μg/ml	2000 μg/ml	
Propiconazole	1000	45.83	58.33	75.00	54.17	66.67	7.18
	1500	70.83	79.17	91.67	79.17	87.50	7.82
	2000	87.50	95.83	100.00	91.67	100.00	7.91
Pyrimethanil	1000	41.67	50.00	66.67	50.00	62.50	8.14
	1500	66.67	79.17	83.33	75.00	83.33	7.56
	2000	83.33	91.67	100.00	87.50	95.83	7.93
Carbendazim	1000	25.00	50.00	66.67	41.67	62.50	9.36
	1500	45.83	62.50	75.00	58.33	66.67	8.28
	2000	70.83	83.33	91.67	79.17	87.50	8.09
Trifloxystrobin	1000	33.33	50.00	70.83	50.00	62.50	10.33
	1500	54.17	66.67	83.33	70.83	79.17	8.67
	2000	75.00	87.50	100.00	87.50	91.67	9.03
Sodium bicarbonate	$1x10^4$*	25.00	-	-	-	-	-
	$2x10^4$*	41.67	-	-	-	-	-
	$3x10^4$*	70.83	-	-	-	-	-
Potassium sorbate	$1x10^4$*	16.67	-	-	-	-	-
	$2x10^4$*	37.50	-	-	-	-	-
	$3x10^4$*	62.50	-	-	-	-	-
L.S.D. at 5%	-	7.18	7.57	8.03	7.96	8.23	-

*The common concentration of salts reviewed from the literature

Table 6. Percentage of control efficiency (PCE) of different concentrations (μg/ml) of fungicides and salts alone or in mixtures against incidence of blue mold on orange fruits caused by *Penicillium italicum*.

Treatments	Conc. μg/ml	Percentage of control efficiency (PCE)					L.S.D. at 5%
		Separated treatment	Candidate sodium bicarbonate concentrations		Candidate potassium sorbate concentrations		
			1000 μg/ml	2000 μg/ml	1000 μg/ml	2000 μg/ml	
Propiconazole	1000	50.00	58.33	87.50	54.17	75.00	7.69
	1500	70.83	83.33	95.83	79.17	91.67	8.01
	2000	91.67	95.83	100.00	95.83	100.00	8.19
Pyrimethanil	1000	41.67	54.17	75.00	50.00	70.83	7.81
	1500	70.83	87.50	95.83	79.17	91.67	8.16
	2000	79.17	91.67	100.00	87.50	100.00	7.79
Carbendazim	1000	33.33	54.17	79.17	54.17	70.83	8.76
	1500	54.17	70.83	83.33	66.67	75.00	9.23
	2000	75.00	91.67	95.83	83.33	91.67	7.69
Trifloxystrobin	1000	37.50	58.33	79.17	54.17	66.67	9.16
	1500	50.00	62.50	87.50	62.50	79.17	9.39
	2000	79.17	91.67	95.83	87.50	91.67	7.79
Sodium bicarbonate	$1x10^4$*	29.17	-	-	-	-	-
	$2x10^4$*	45.83	-	-	-	-	-
	$3x10^4$*	70.83	-	-	-	-	-
Potassium sorbate	$1x10^4$*	25.00	-	-	-	-	-
	$2x10^4$*	45.83	-	-	-	-	-
	$3x10^4$*	58.33	-	-	-	-	-
L.S.D. at 5%	-	7.88	7.37	7.94	9.31	7.78	-

*The common concentration of salts reviewed from the literature

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green mould disease. Middle East J. Agric. Res., 3 (2): 240-247

Kanetis, L.; Forster, H. and Adaskaveg, J. E. (2008 a): Baseline sensitivities for new postharvest fungicides against Penicillium spp. on citrus and multiple resistance evaluations in *P. digitatum*. Plant Dis., 92: 301-310.

Kanetis, L.; Forster, H. and Adaskaveg, J. E. (2008 b): Optimizing efficacy of new postharvest fungicides and evaluation of sanitizing agents for managing citrus green mold. Plant Dis., 92: 261-269.

Khalifa, H.M.S. and Sameer, W.M. (2014): Control of the green mold of orange using fungicides alone and in combination with antioxidants. Middle East J. App. Sci. 3(2): 351-358.

Marei, G.I.Kh. and Abd-Elgaliel, S.A.M. (2018): Antifungal potential and biochemical effects of monoterpenes and phenylpropenes on plant pathogenic fungi. Plant Protect. Sci., 54 (1): 9-16.

McKay, A.H.; Forster, H. and Adaskaveg, J. E. (2012 a): Efficacy and application strategies for propiconazole as a new postharvest fungicide for managing sour rot and green mold of citrus fruit. Plant Dis., 96: 235-242.

McKay, A.H.; Forster, H. and Adaskaveg, J. E. (2012 b): Toxicity and resistance potential of selected fungicides to Galactomyces and *Penicillium* spp. causing postharvest fruit decays of citrus and other crops. Plant Dis., 96: 87-96.

Montesinos-Herrero, C.; Smilanick, J.L.; Tebbets, J.S.; Walse, S. and Palou, L. (2011): Control of citrus postharvest decay by ammonia gas fumigation and its influence on the efficacy of the fungicide imazalil. Postharvest Biology and Technology, 59: 85-93.

Montesinos-Herrero, C.; Angeldel-Rio, M.; Paster, C.; Brunetti, O. and Palou, L. (2009): Evaluation of brief potassium sorbate dips to control postharvest Penicillium decay on major citrus species and cultivars. Postharvest Biology and Technology, 52: 117-125.

Palou, L. (2014): *Penicillium digitatum*, *Penicillium italicum* (green mold, blue mold). In: Bautista – Banos, S. (Ed.), Postharvest Decay. Control Strategies. Academic Press, Elsevier Inc., London, UK, pp. 45-102.

Palou, L. (2018): Postharvest treatments with GRAS salts to control fresh fruit decay. Horticulturae, 4, 46.

Palou, L.; Smilanick, J.L. and Crisosto, C.H. (2009): Evaluation of food additives as alternative or complementary chemicals to conventional fungicides for the control of major postharvest diseases of stone fruit. J. Food Prot., 72: 1037-1046.

Palou, L.; Smilanick, J.L. and Droby, S. (2008): Alternatives to conventional fungicides for the control of citrus postharvest green and blue moulds. Stewart Postharvest Rev., 4: 1-16.

Palou, L.; Smilanick, J.L.; Usall, J. and Vinas, I. (2001): Control of postharvest blue and green molds of oranges by hot water, sodium carbonate and sodium bicarbonate. Plant Dis., 85: 371-376.

Parra, J.; Ripoll, G. and Orihuel-Iranzo, B. (2014): Potassium sorbate effects on citrus weight loss and decay control. Postharvest Biology and Technology, 96: 7-13.

Sameer, W.M. and Ibrahim, I.S. (2019): Effectiveness of pH and butylated hydroxyanisole (BHA) on fungicidal activity of certain fungicides for controlling green and blue mold diseases on orange fruits. J. Plant Prot. and Path., Mansoura Univ., 10 (4): 217-223.

Samoucha, Y. and Cohen, Y. (1989): Field control of potato late blight by synergistic fungicidal mixtures. Plant disease 73:751-753.

Smilanick, J.L.; Mansour, M.F.; Gabler, F.M. and Sorenson, D. (2008): Control of citrus postharvest green mold and sour rot by potassium sorbate combined with heat and fungicides. Postharvest Biology and Technology, 47: 226-238.

Snedecor, G.W. and Cochran, W.G. (1969): Statistical method. The lowa Status Uni. Press, Ames, IA593pp.

Valencia-Chamorro, S.A.; Palou, L.; del Rio, M.A. and Perez-Gago, M.B. (2008): Inhibition of Penicillium digitatum and Penicillium italicum by hydroxypropyl methylcellulose lipid edible composite film containing food additives with antifungal properties. J. Agric. Food Chem., 56: 1270-1278.

Youssef, K.; Abd-Elsalam, K.A.; Hussien, A.; sanzani, S.M. and Ippolito, A. (2017): Organic and inorganic salts as postharvest alternative control means of citrus. Chapter 8, Pages 161-212 in: Citrus Pathology: Volume Harsimran Gill and Harsh Garg. Cornell University, USA.

Zamani, M.; Sharifi-Tehrani, A.; Ahmadzadeh, M.; Behboudi, K. and Hosseininaveh, V. (2008): Biological control of *Penicillium digitatum* on oranges using *Pseudomonas* spp. either alone or in combination with hot sodium bicarbonate dipping. Australasian Plant Pathology, 37: 605-608.

Zamani, M.; Sharifi-Tehrani, A.; Ahmadzadeh, M.; Hosseininaveh, V. and Mostofy, Y. (2009): Control of *Penicillium digitatum* on orange fruit combining Pantoea agglomerans with hot sodium bicarbonate dipping.Journal of Plant Pathology, 91: 437-442.

Zhang, J. and Swingle, P. (2003): Control of green mold on Florida citrus fruit using bicarbonate salts. Proc. Fla. State Hort. Soc. 116: 375-378.

مكافحة أعفان الثمار باستخدام مبيدات الفطريات و الاملاح الامنة منفردة وفي مخاليط

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الملخص العربي:

تم تقييم اربعة من مبيدات الفطريات (بروبيكونازول و بايريميثانيل و كاربيندازيم و ترايفلوكسيستروبين) و اثنان من الاملاح الامنة (بيكربونات الصوديوم و سوربات البوتاسيوم) منفردين و في مخاليط ضد مرضي العفن الاخضر و الازرق في البرتقال ابو سره المتسببين عن فطري بنسيليوم ديجيتاتم و بنسيليوم ايتاليكام. أظهرت التجارب المعملية ان الفطرين كانا لهما حساسية مرتفعة لمبيدات بروبيكونازول و بايريميثانيل و ترايفلوكسيستروبين و حساسية متوسطة لمبيد كاربيندازيم. الاملاح كانت اقل فعالية من المبيدات و كان سوربات البوتاسيوم اقل فعالية من بيكربونات الصوديوم. من المثير للاهتمام ان اضافة الاملاح الى البيئة المعاملة بالمبيدات كان سببا في زيادة فاعليتها ضد الفطرين. التجارب التي اجريت على البرتقال في المعمل اوضحت ان المعاملات بجميع المركبات كانت فعالة في مكافحة المرضين. و ان اضافة الاملاح الى المبيدات سببت زيادة فعاليتها ضد حدوث الاصابة بمرضي العفن الاخضر و العفن الازر.